Summary ?

Andrea Comastri

INAF- Osservatorio Astr. Di Bologna

“Warm” topics (a highly biased view of some scientific issues which cannot be investigated without X-rays)

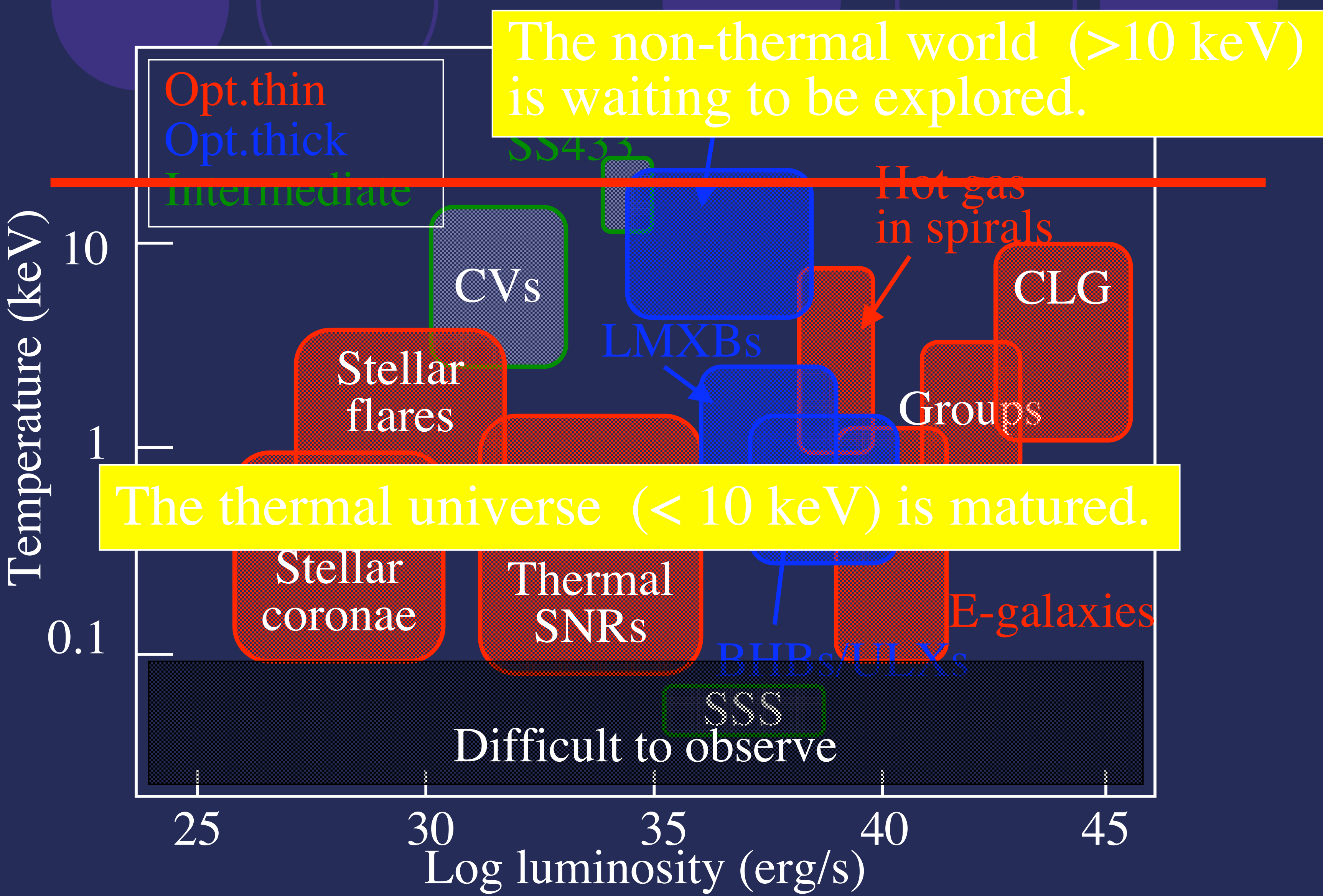
- Violent / Hidden Universe
- Fundamental Physics (GR, EOS)

- Baby (high redshift) Universe
- Evolving Universe

- A few words about polarimetry

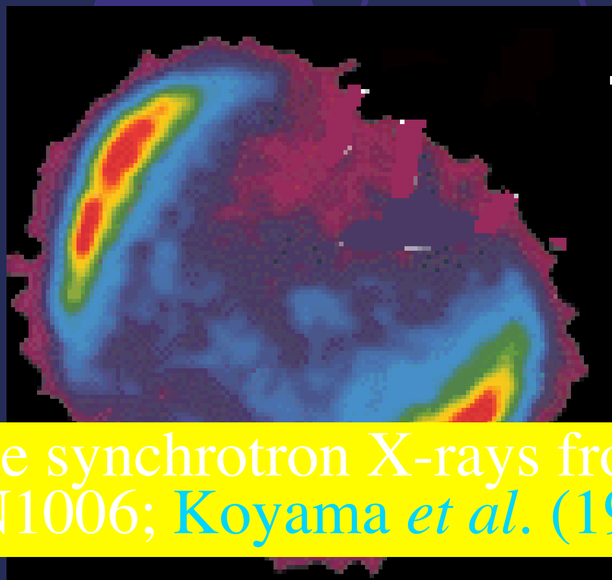
The hard X-ray universe is full of novel surprises that cannot be accessed via other means. An extension of the *XEUS/Con-X* energy band into higher energies would be highly desired.

1c. The "hot universe" below ~10 keV

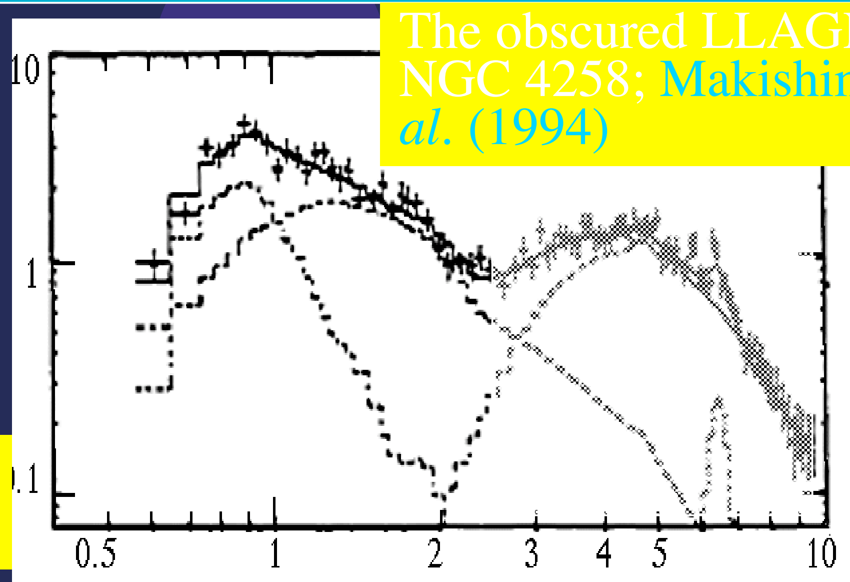


2005

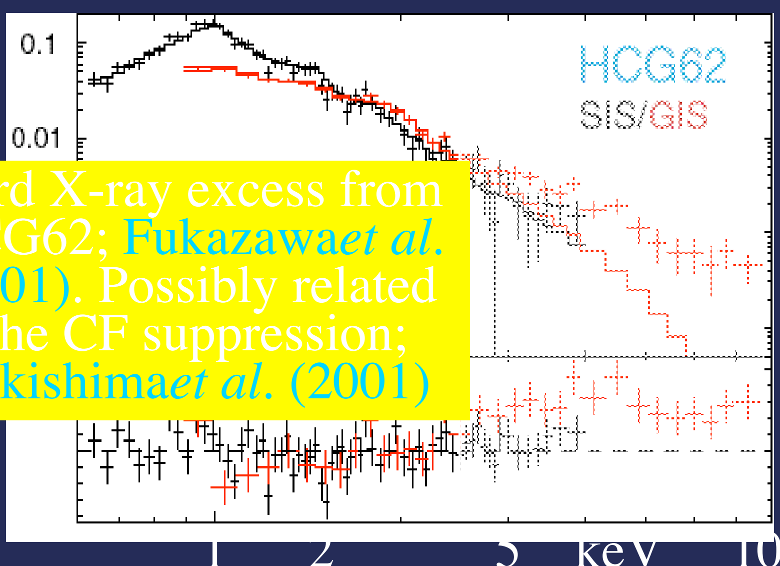
2b. Highlights from the *ASCA GIS*



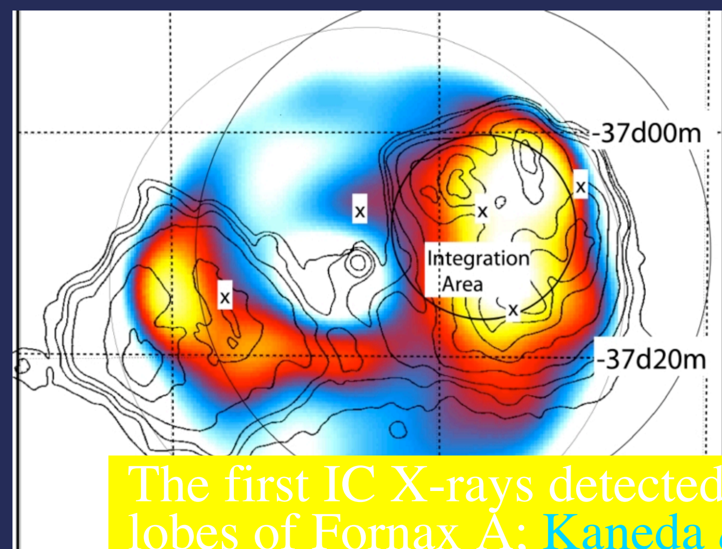
The synchrotron X-rays from SN1006; Koyama *et al.* (1995)



The obscured LLAGN in NGC 4258; Makishima *et al.* (1994)



Hard X-ray excess from HCG62; Fukazawa*et al.* (2001). Possibly related to the CF suppression; Makishima*et al.* (2001)



The first IC X-rays detected from lobes of Fornax A; Kaneda *et al.* (1995) , Tashiro *et al.* (2001)

Sites of particle acceleration

- Massive star forming regions
- Accreting compact objects
- Jets from compact Galactic sources
- Stellar flares
- Pulsar Wind Nebulae
- Gamma ray bursts

- High energy Cosmic Rays have to come from somewhere, and observations have called into question SNRs as the prime candidate
- Blazars
- Cluster Mergers (hard tails)

Observational Questions

(specific to X-rays and derived from astrophysics questions)

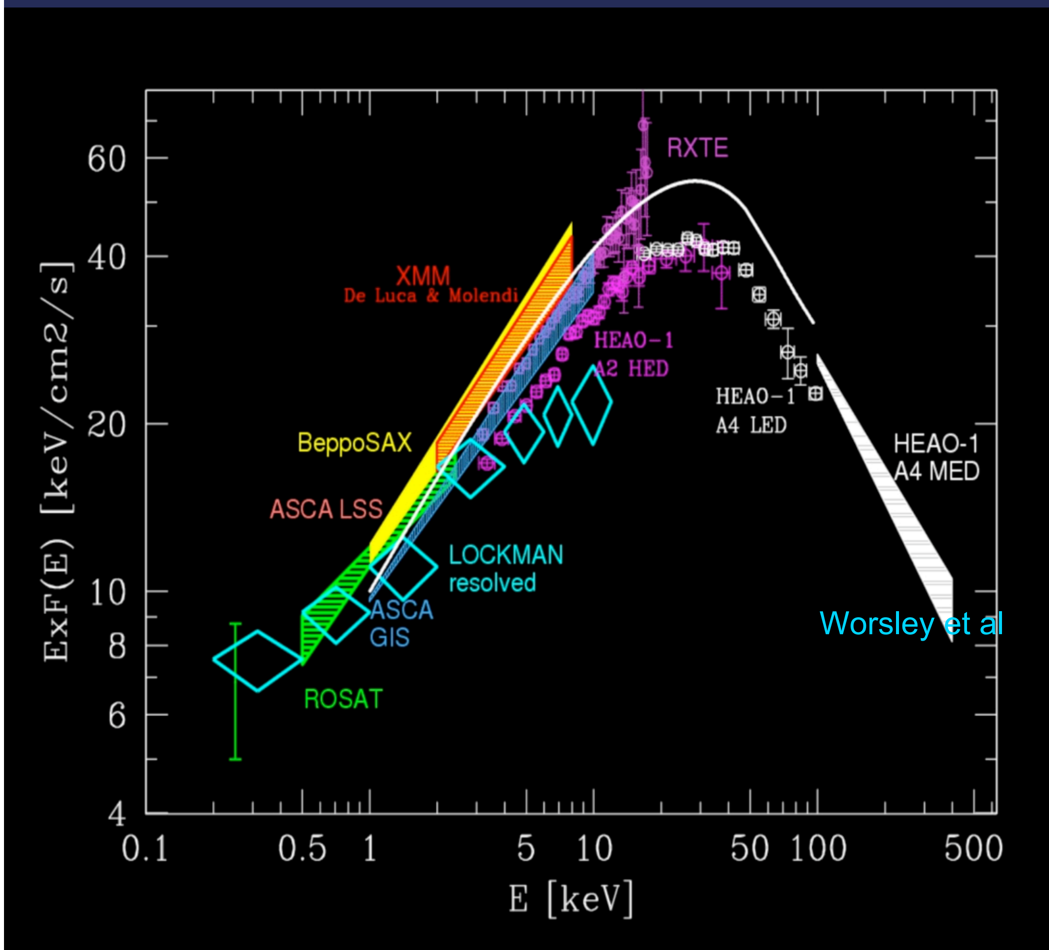
- What is the photon emission mechanism?
- What is the relationship between the X-ray emitting region and emission in other bands (radio, TeV)?
- What is the energy spectrum of the accelerated particles (including E_{max})?
- How does this spectrum evolve with source age?
- What are the conditions in the acceleration region?

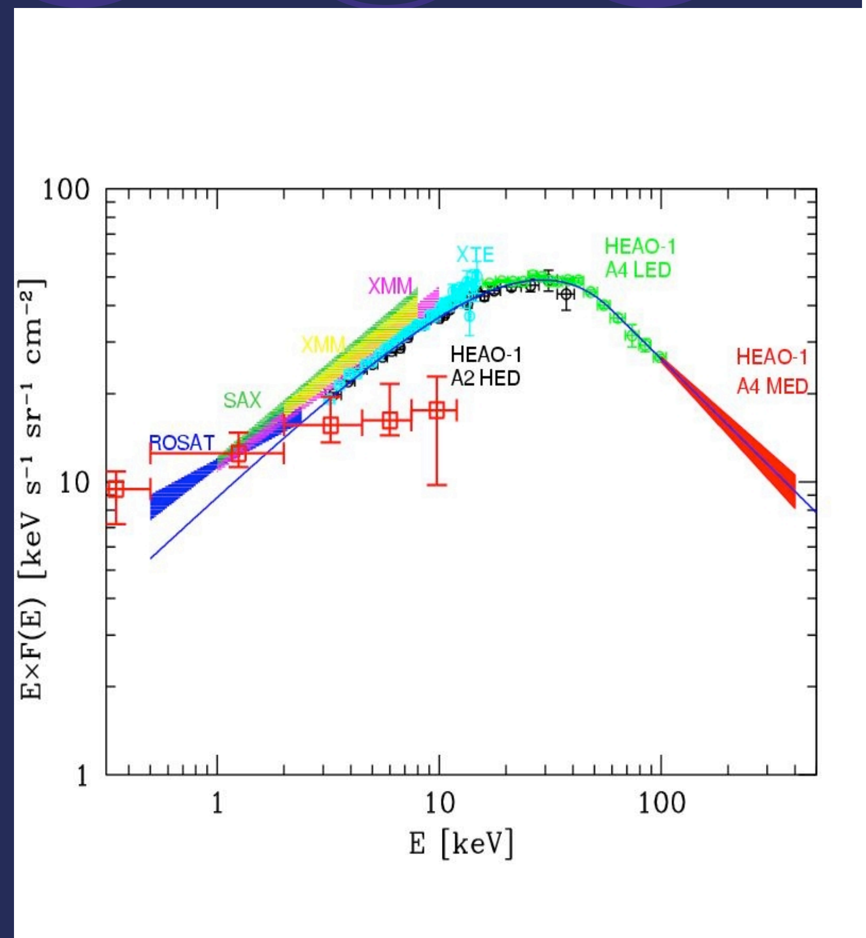
Hidden (AGN) Universe

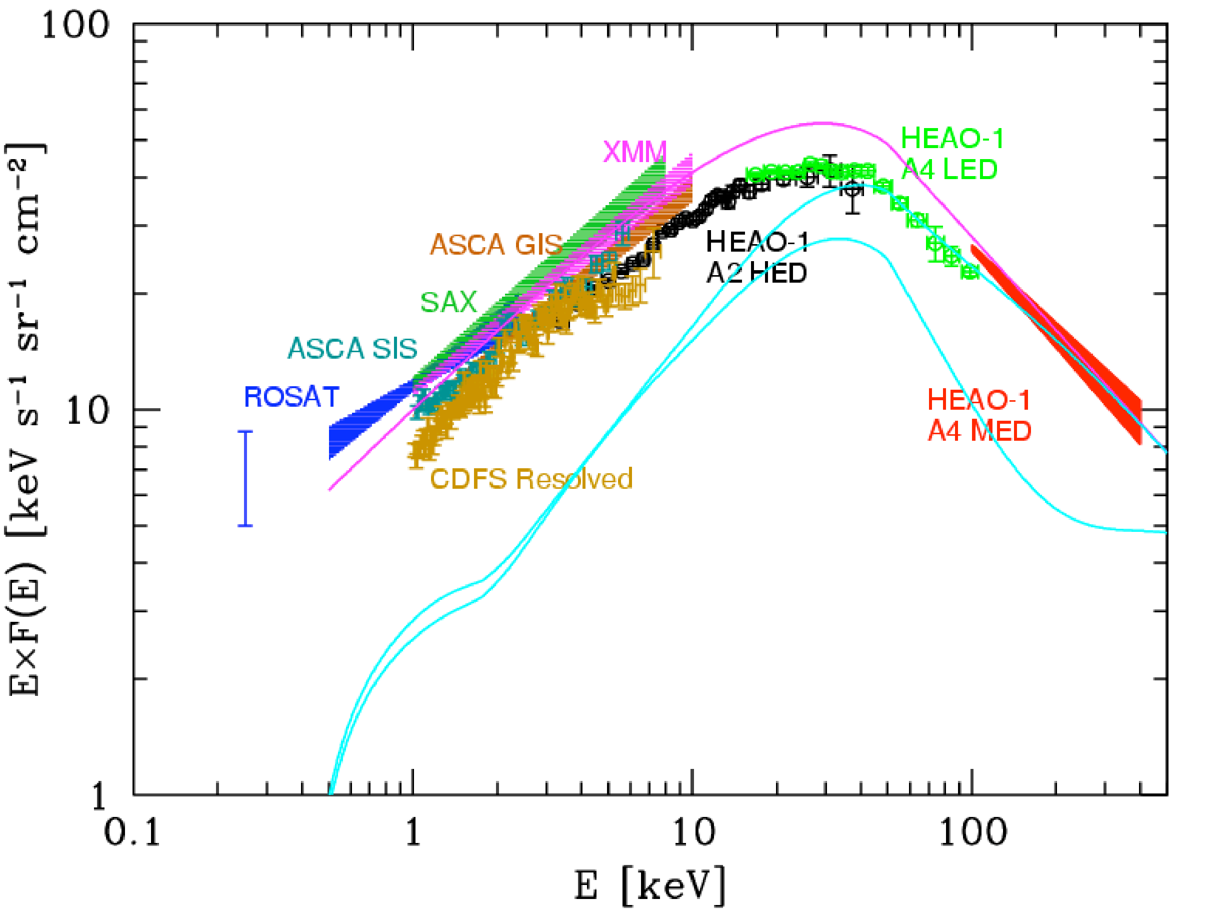
The most sensitive surveys have effective energies of a few keV ◊ half of the 5-10 keV XRB still unresolved

- How common is Compton thick absorption beyond the local Universe ?
- High energy cut-offs or continuum breaks ?
- Physics and evolution of the SMBH at the XRB peak (30 keV)
- We do expect to recover the XRB synthesis predictions, but you never know

X-ray background and resolved fraction







Residual background
Spectrum after model
Subtraction

Magenta lines: analtyic
Fit from Gruber et al

Upper curve: renormalized
Upward by 30 %

Green lines
Residual spectrum from
Original Gruber fit

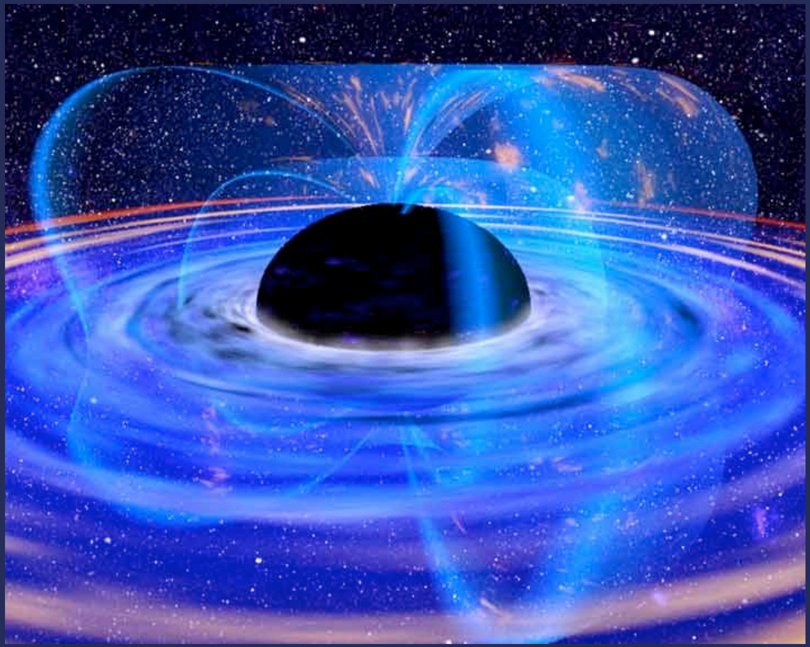
Cyan lines
Residual spectrum form
Renormalized Gruber fit

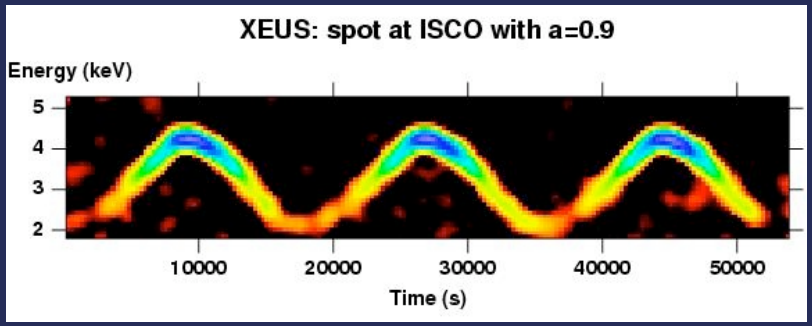
Strong Gravity, GR

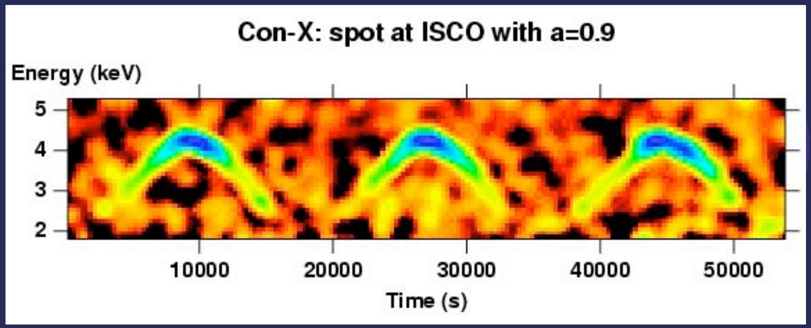
- Where does GR "break"?
  - All expected failure points are in extreme regimes (Planck scales around a "spacetime singularity"; or on length scale of any compactified extra dimensions)
- We should not <u>expect</u> to find deviations from General Relativity around our black holes
  - Require fundamental modifications to the foundations of the theory to obtain any relevant deviation from GR
  - See the "Six Ways to Axiomatize Einstein's Theory" in MTWs *Gravitation*

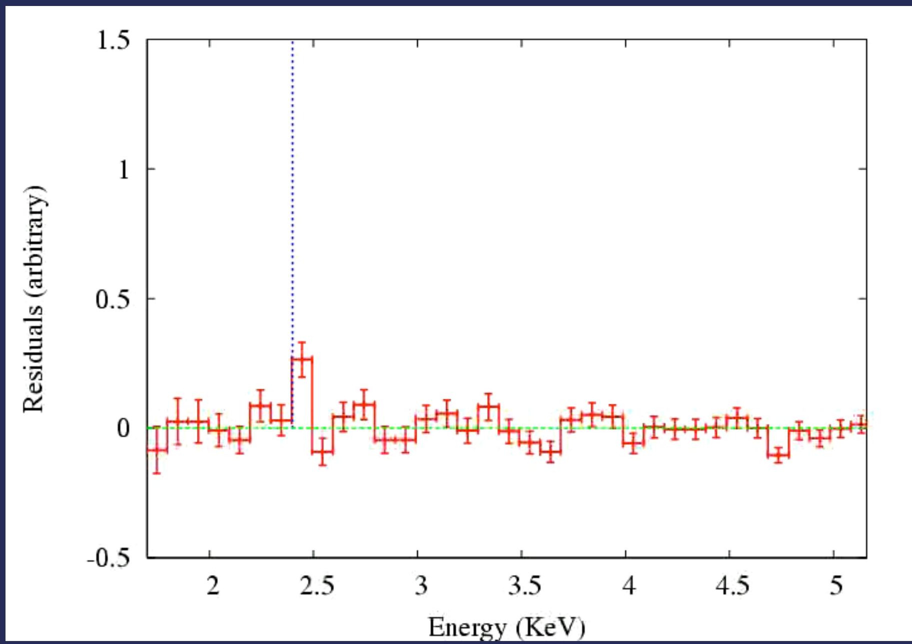
… and black hole astrophysics

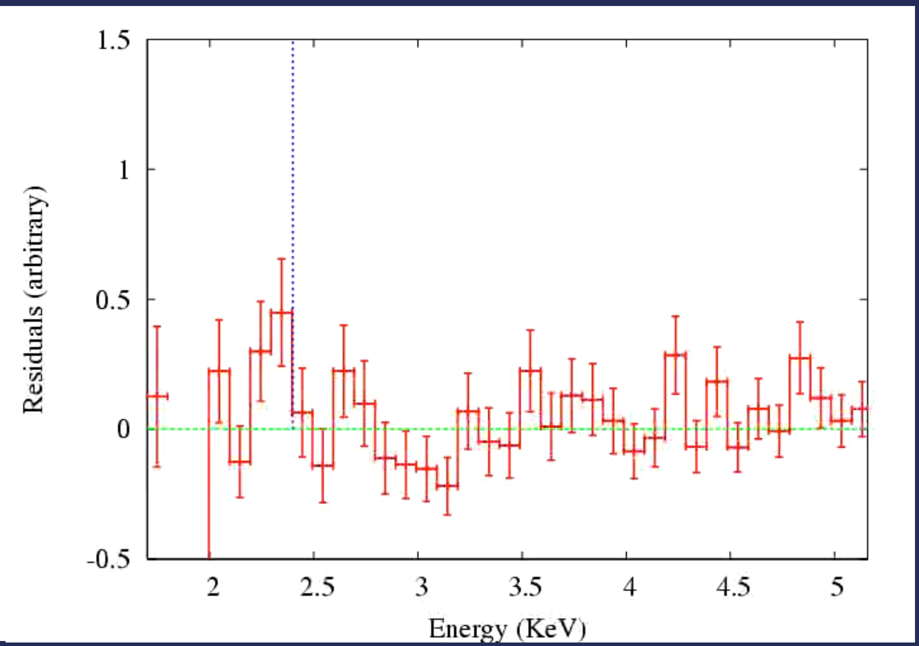
- Will focus on observing physics in the strong field background
  - Relativistic dynamics of matter & energy close to BHs
  - Astrophysics of BH spin
  - Physics of the most powerful sources in the Universe
  - Along the way… verify or falsify predictions of GR
- We must let ourselves









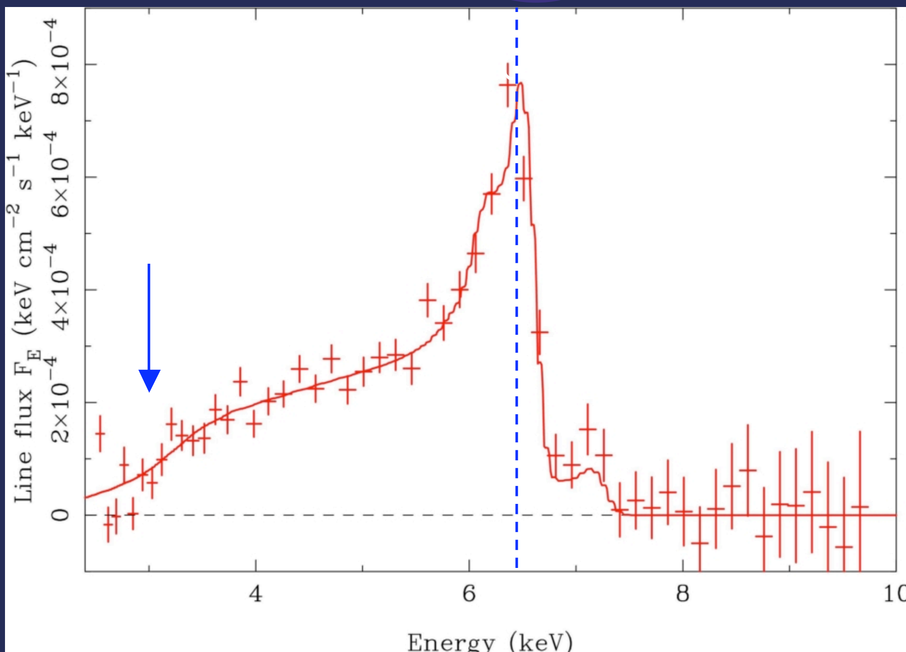


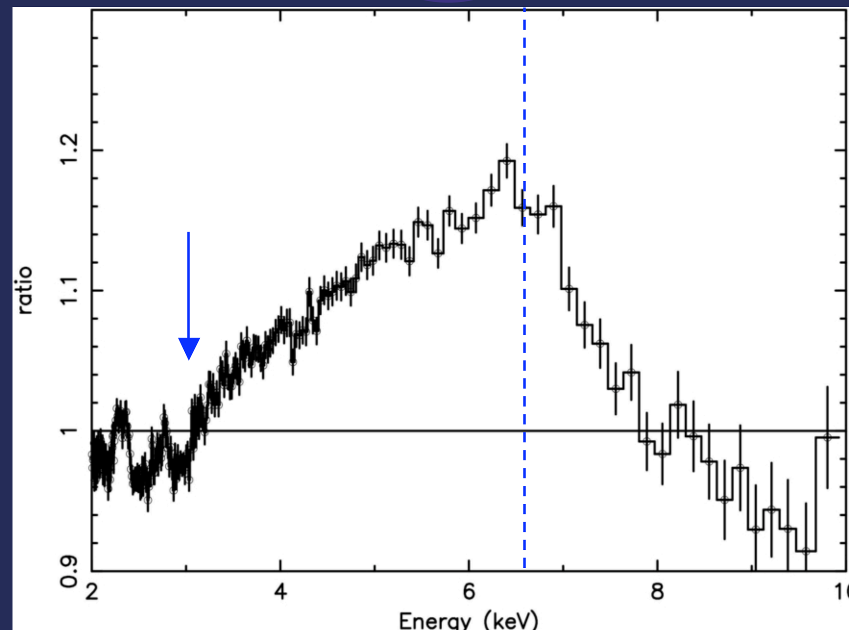
$F(2\text{-}10)=2\times10^{-12}$; $M=1.2\times10^{8}$; i=30deg

Orbiting spot at $2.4r_g$, P=18ks

Simulation by Giovanni Miniutti

BHC – Seyfert Connections





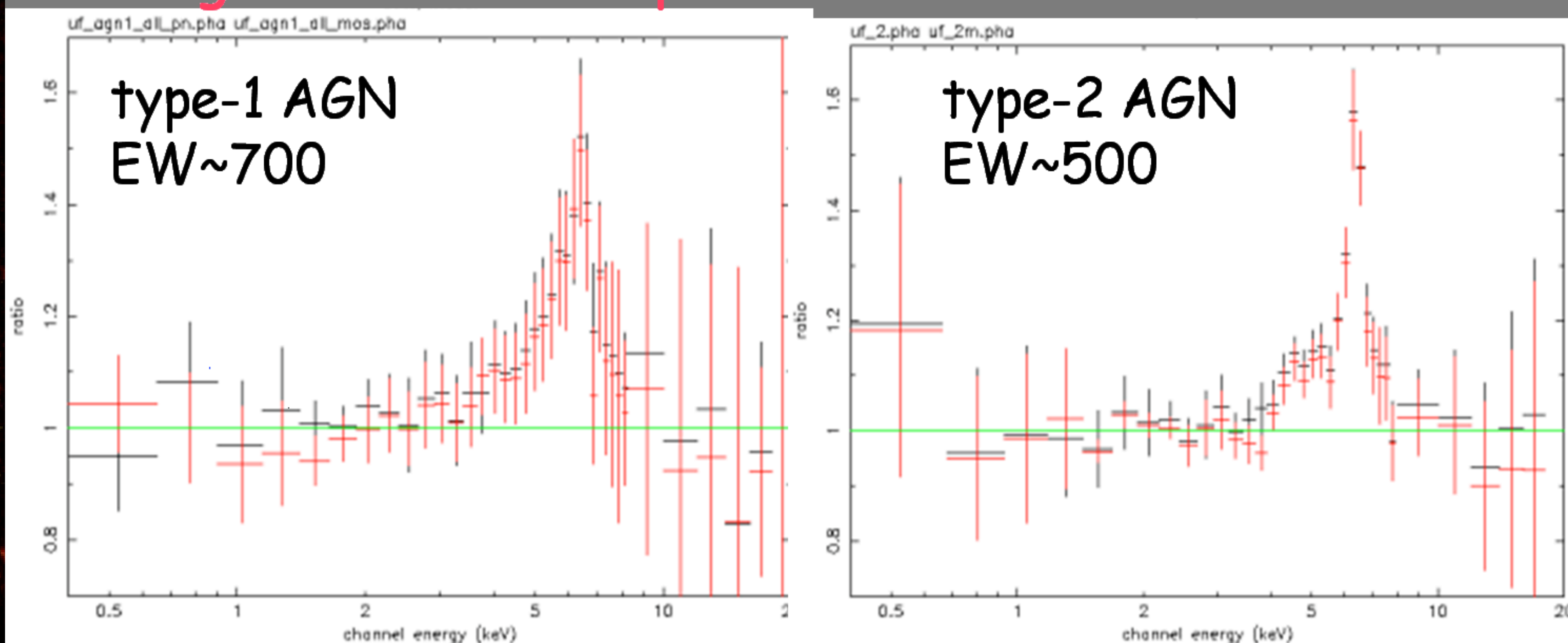
- Both lines require R_{in} ~ 2 R_g, high spin (a/M > 0.8-0.9 or so).
- Centrally concentrated emission, J(r) ~ r^{-q}, q =4-5 (q=3 expected).
- Inner accretion flows must be *remarkably* similar.

Lockman Hole

800 ks XMM-Newton observation

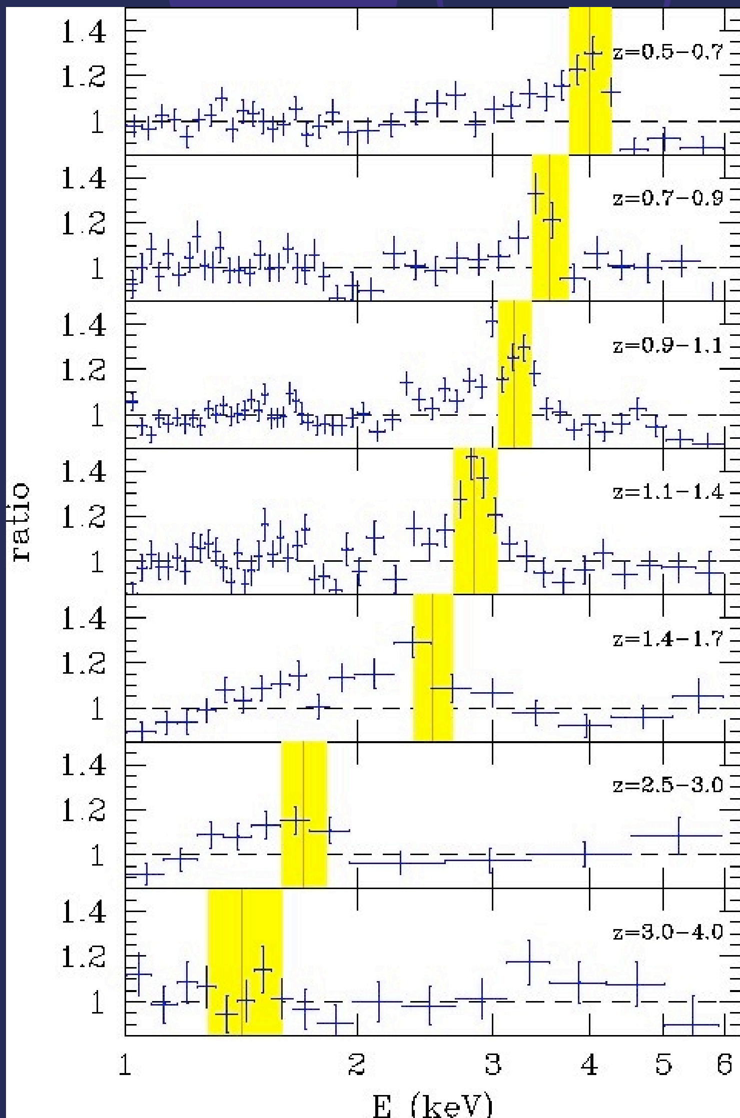
Hasinger

Average rest-frame spectra show relativistic Fe-lines



Streblyanskaya et al 2004

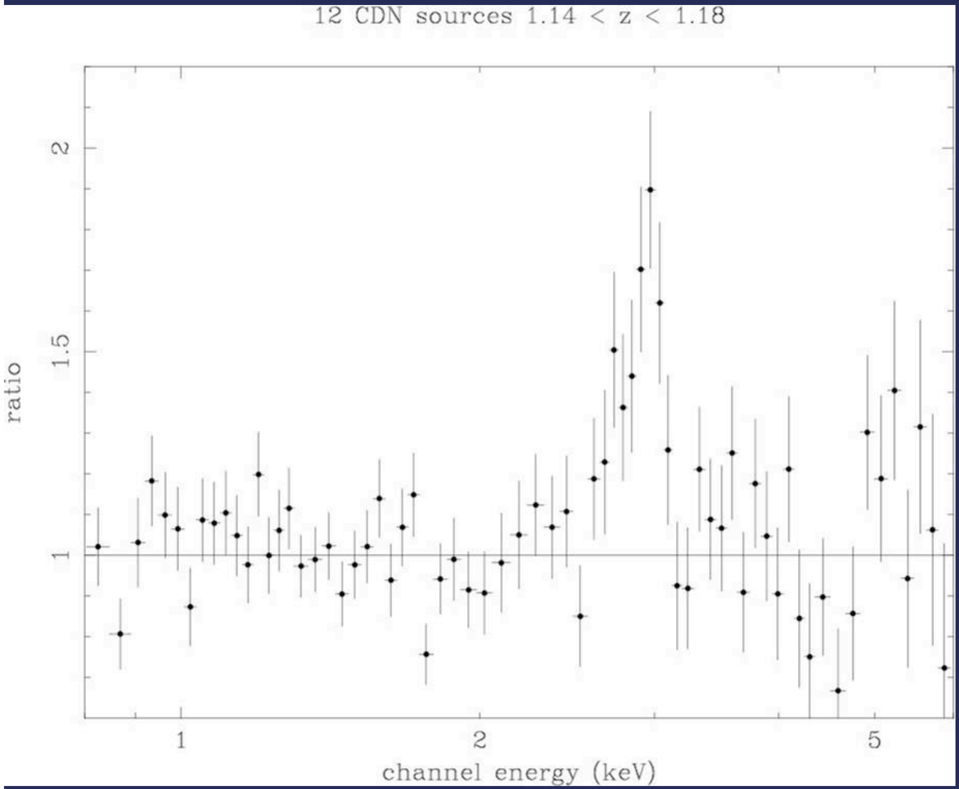
Is there a broad component ?

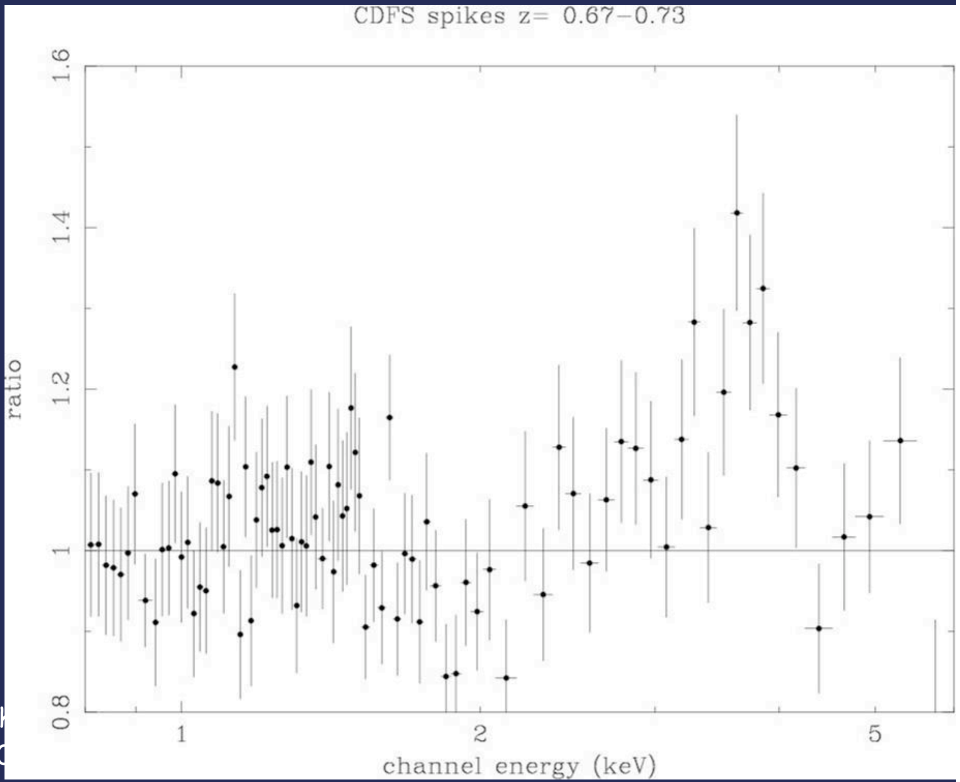


Presence of red wings?
(similar to Streblyanskaya et al. 2005 results)

Brusa, Gilli, AC 2005

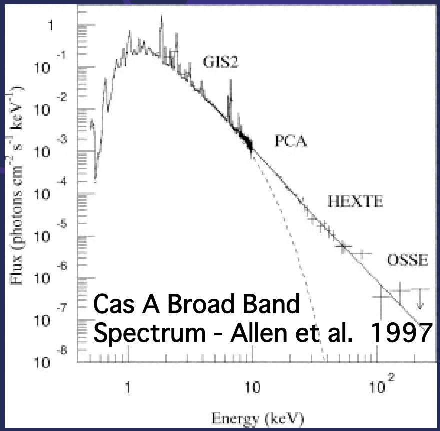
Stacked spectra around redshift spikes in CDFN and CDFS (1.1 and 0.7)





Requirements needed/desired

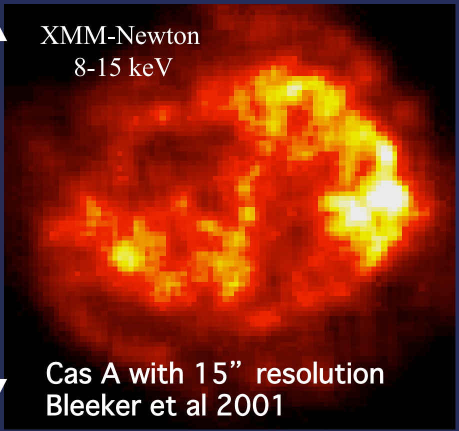
- Bandpass 1-100 keV
- Field of view - ~10 - 15 at all energies
- Angular resolution - <15" above 10 keV to reach 0.1 mCrab (10-30) or 80% of the XRB
- Low background for SB studies
- Effective area: Current HXT provides 10+ keV sensitivity in 100 ks to a surface brightness of 2×10^{-13} erg $arcmin^{-2}$ cm^{-2} s^{-1}
  - Arc minute spectroscopy of tail in cluster with 10 percent of $L_x \sim 10^{45}$ erg s^{-1} at z=0.05 with nominal HXT area
  - Would prefer larger effective area!



30’

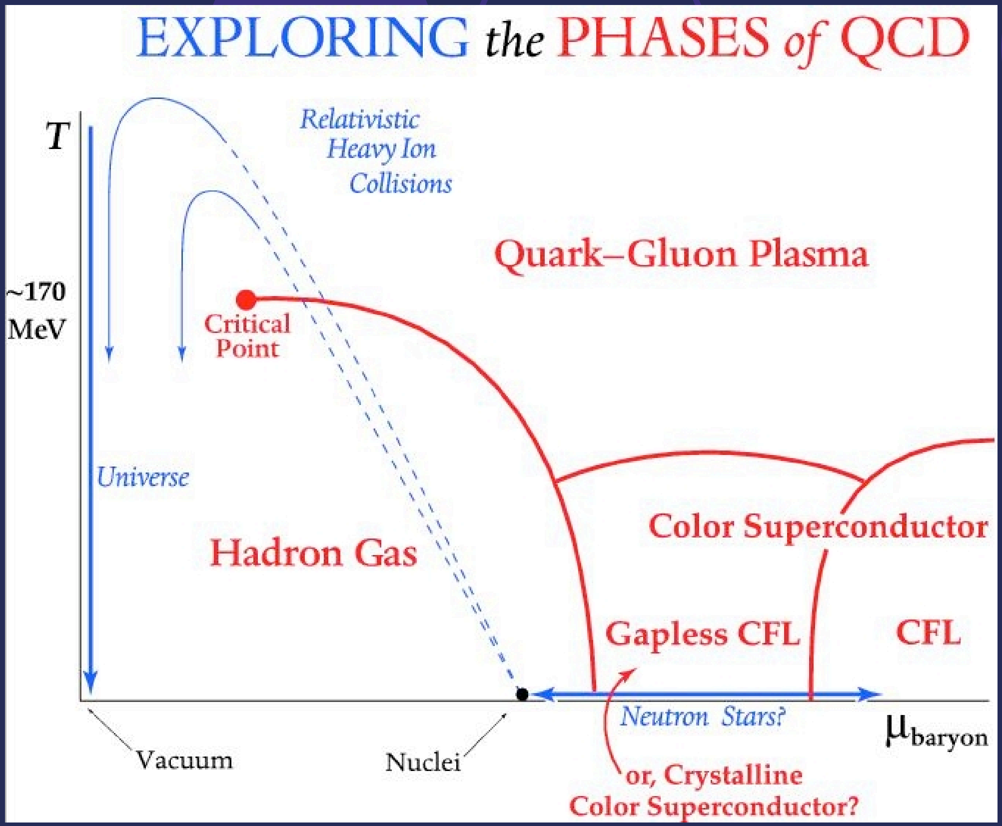

SN1006 Chandra mosaic

5’



Cas A with 15” resolution
Bleeker et al 2001

The "Condensed Matter Physics" of QCD



Krishna Rajagopal (2004)

- The early universe explored the high temperature regime

- Relativistic heavy ion collision experiments are exploring transition to quark-gluon plasma

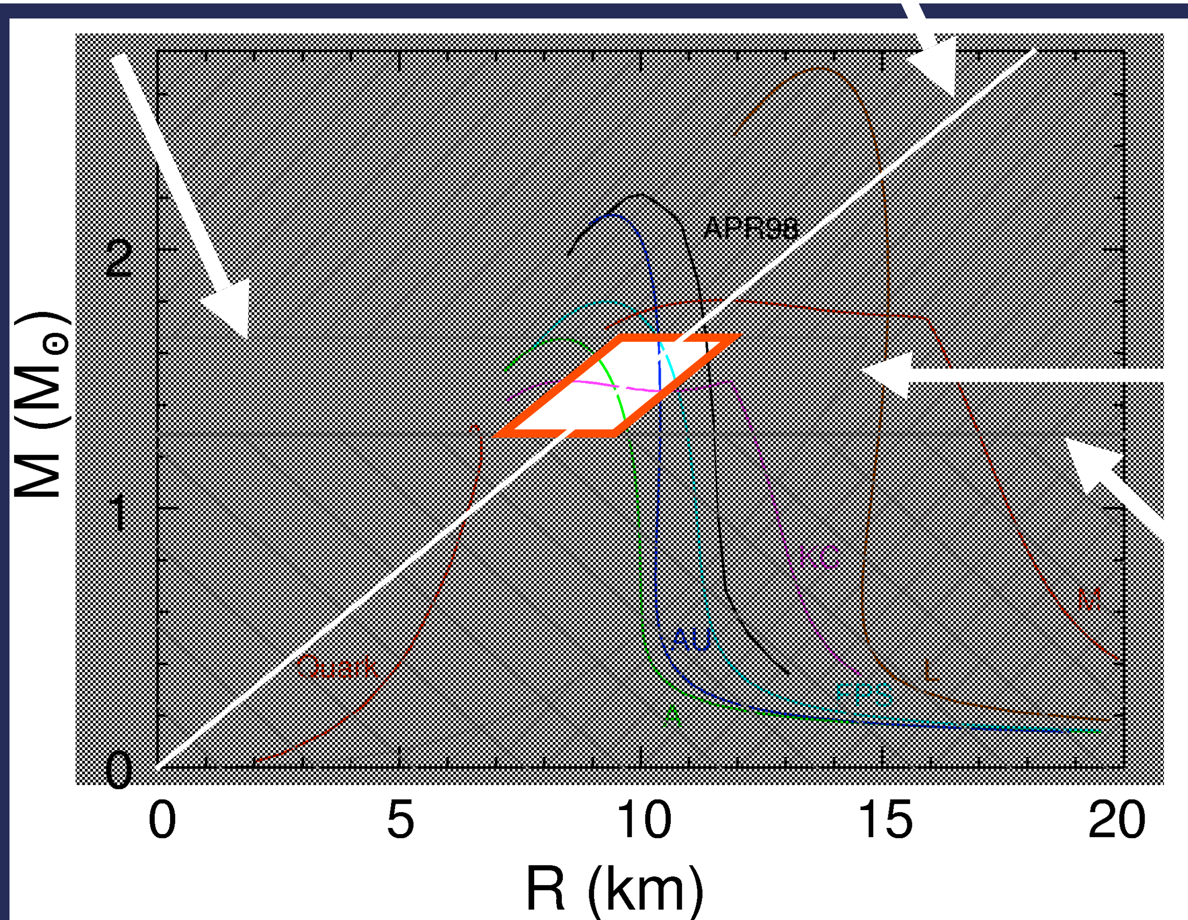
- The high density "low" temperature regime is inaccessible to laboratory experiment. The only way to study this regime is through the astrophysics of neutron stars.

EOS - Combined constraints

$R \leq 14.6\ (M / M_\odot)^{1/3}\ (\nu/1000\ \mathrm{Hz})^{-2/3}$ km

$\frac{M}{R} = 0.153 \pm 0.001\ M_\odot/\mathrm{km}$

$M \leq 2.2\ (\nu/1000\ \mathrm{Hz})^{-1}\ M_\odot$



$M \sim 1.3\ M_\odot$

Critical capabilities

.

- Band pass: ~0.3 keV – 25keV (~0.5 Å – 30 Å)

  Lower bound to detect high-order Paschen lines.
  Upper bound to constrain continuum around Fe Lyα.
  Amplitude of variability increases with energy.

- Spectral resolution: ~3 eV at 1 keV

  For typical rotational/pressure broadening.

- Effective area: As large as possible.

  At least 10 m^2 for single-burst line detection (for slow/moderate rotators).

  See talk by Didier Barret.

Max. count rate: ~5 x 106 counts/s (see Didier Barret's talk).

Pile-up may be a problem. Defocusing?

Time resolution: t ~ 10 ms or less

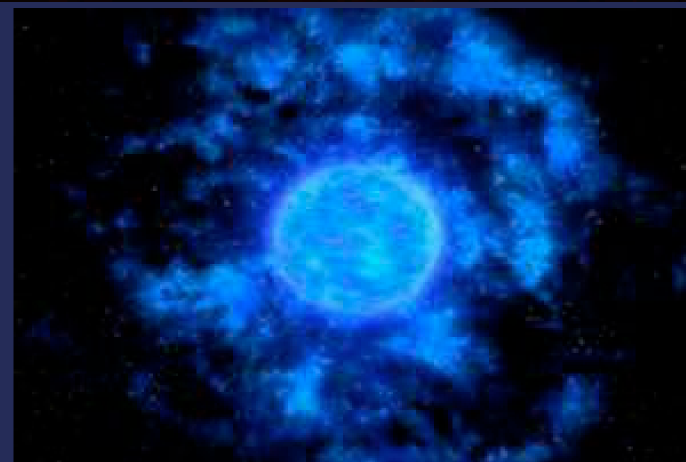
The first Black Hole

Before the first star can form, the universe has to cool down to ~100K to allow molecular hydrogen cooling.

The first star is expected to be massive (~300 $M_{\odot}$), shines for ~1 Million years, sterilizes its cosmic environment, explodes in a GRB hypernova, pollutes its environment with heavy elements and leaves a seed Black Hole.

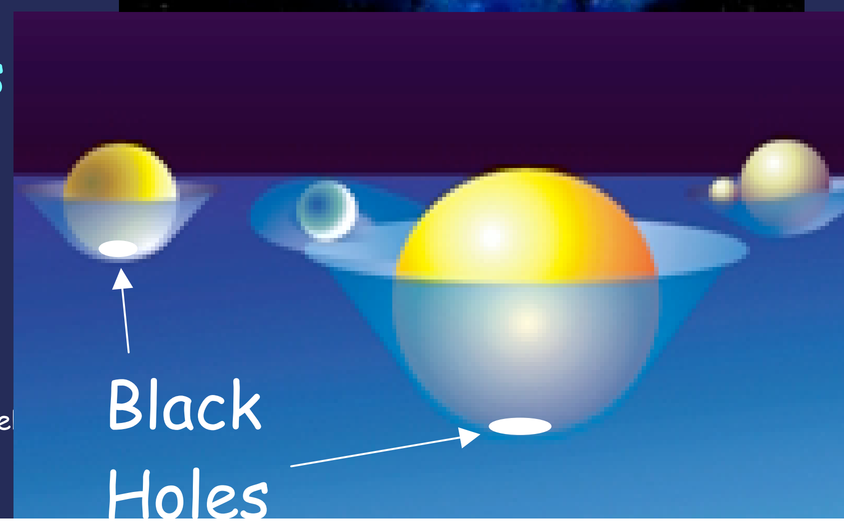
While the galaxy forms, the BH continues to grow exponentially, quickly producing a powerful quasar, if enough fuel can be provided.

Sensitive X-ray observations can study the first GRB explosions and can detect



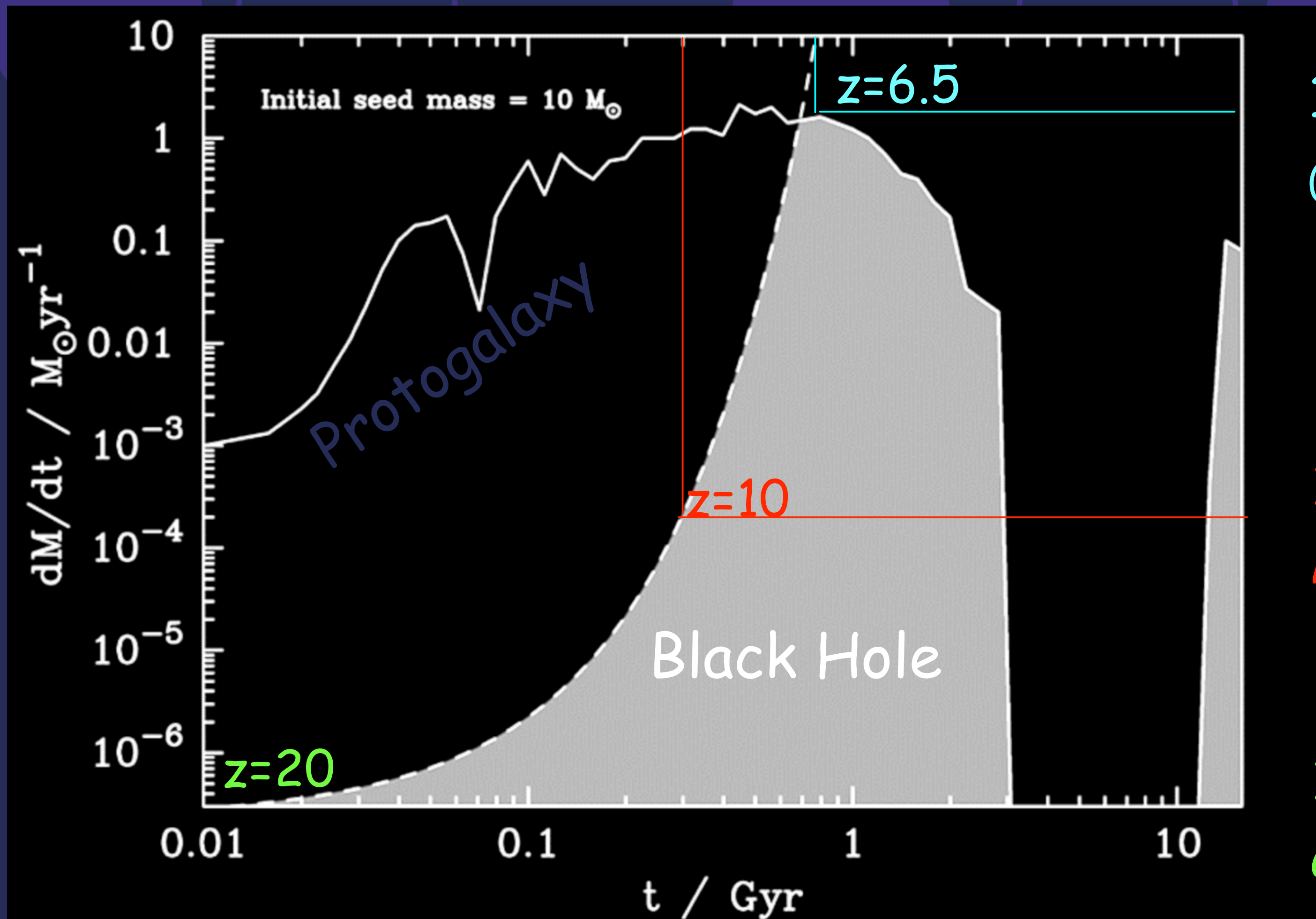
Tom Abel & Discovery

NASA



QSO exponential feeding

Archibald et al. 2001



10^8 $M_\odot$

(known QSOs)

10^4 $M_\odot$

Mini-QSOs

10 $M_\odot$

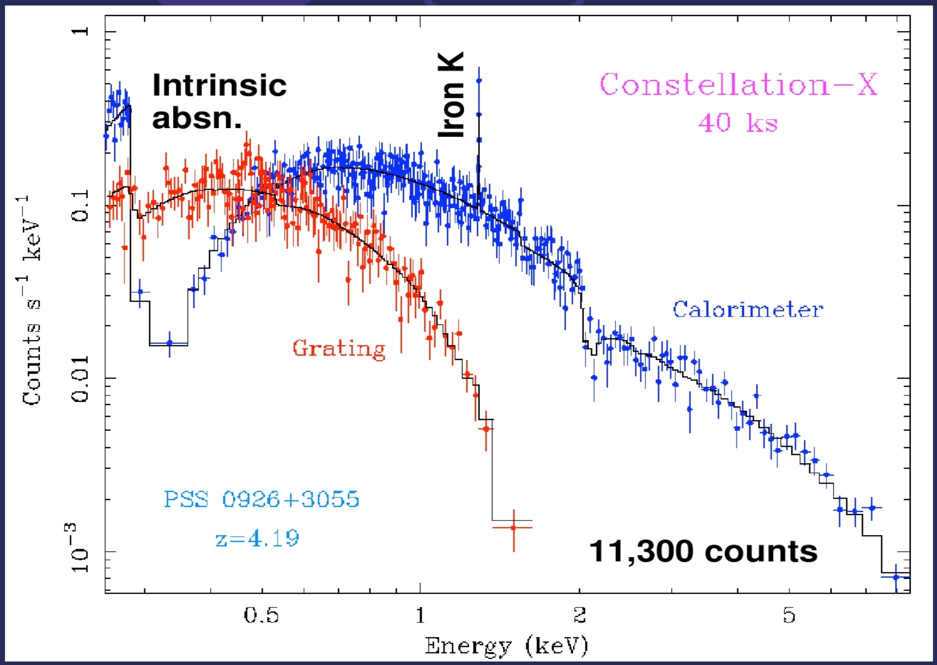
Gamma Burst

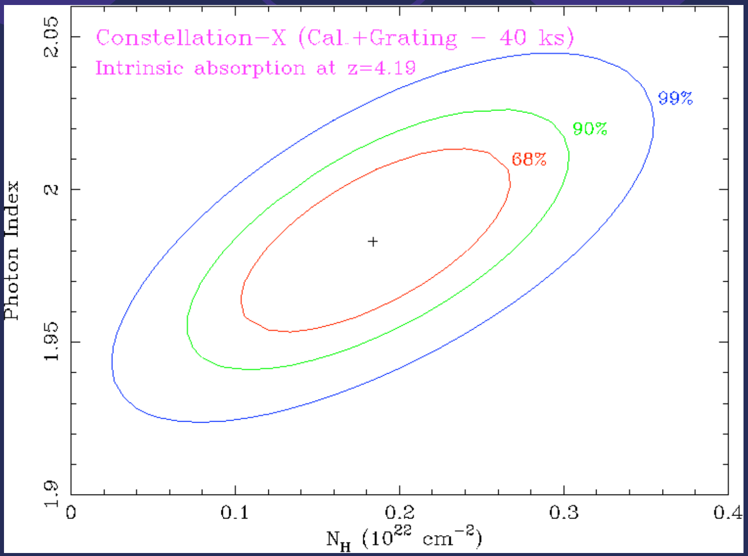
Need ew eneration -ray elescope to detect and study BH in conjunction with forming galaxy (S_{min} ~ 10^{-18} erg cm^{-2} s^{-1}).

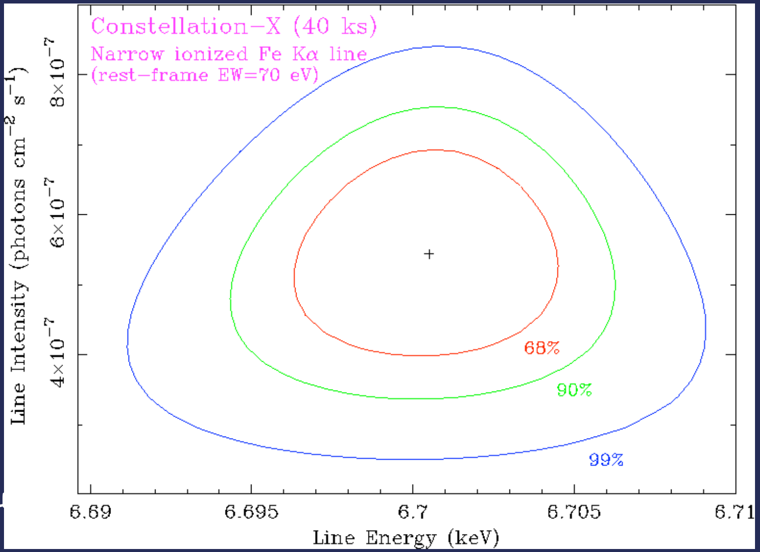
10^4 $M_\odot$ @ redshift 10 detectable.

Prospects for Constellation-X and XEUS - 2

Simulated Constellation-X Spectra







Con-X and XEUS would allow efficient spectroscopy and variability studies for many z > 4 AGNs.

Absorption column and ionization, Fe K line properties, continuum spectral shape.

Can we Really Find Distant Clusters ?

1. Redshift record breaking luminous X-ray cluster found in the XMM archive by MPE-ESO-AIP collaboration ◊ Announcement by Chris Mullis et al. on 2. 3. 2005 in Kona !

Task for ConX-XEUS

- To best characterize :

abundant clusters at z ~ 2 M ~ 3 1013 h-1 Msun

2. more rare clusters „ M ~ 1014 h-1 Msun

λ Scientific Requirements

- ϒ Sensitivity: 10^{-18} erg cm^{-2} s^{-1} _ > 10 m^2 area @1 keV
- ϒ Angular resolution 2-5 arcsec

  depending also form the number counts

  of faint normal galaxies

For high - z clusters

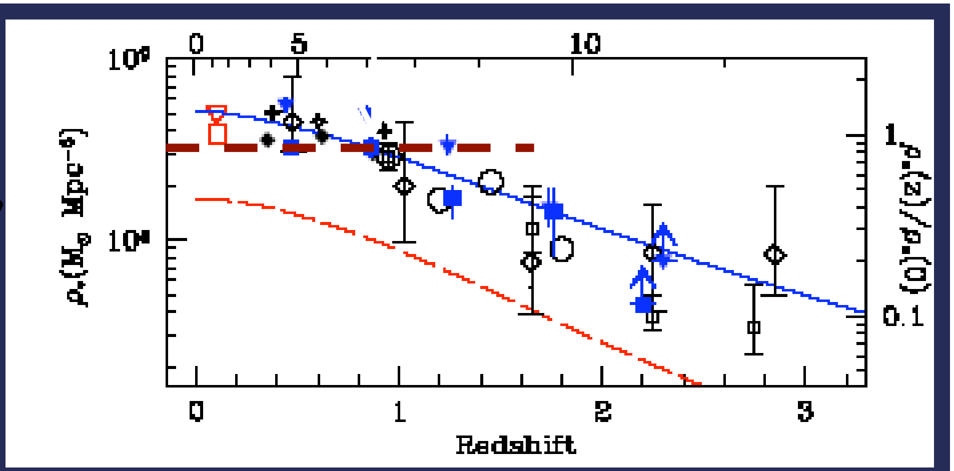
FOV

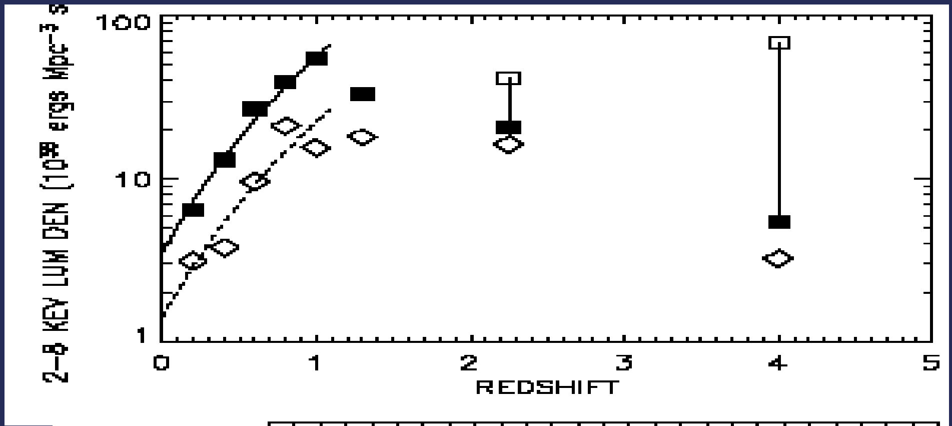
Low Background

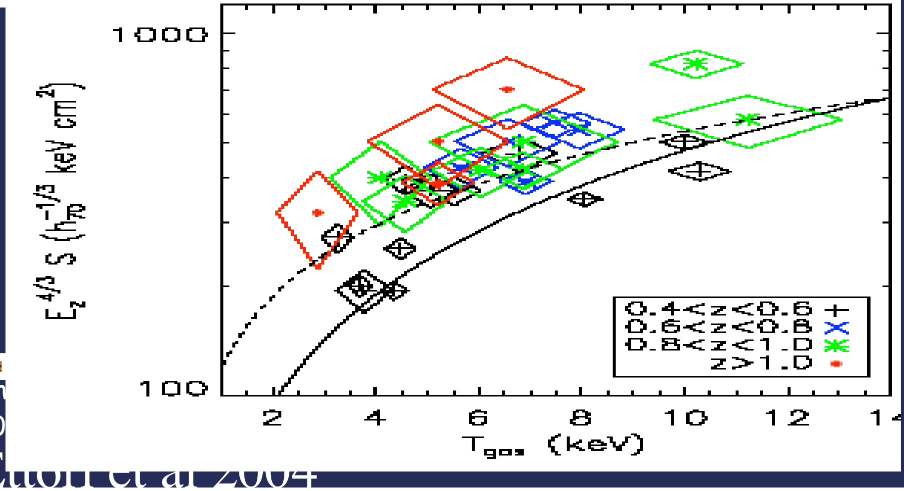
spectral resolution (a few eV)

How the universe came to be the way it is

- at z>1.5 the universe is very different from today
  - Most stars in the universe formed from 0.3<z<1.5
  - The epoch of black holes is z~1
  - Cluster evolution is doing something quite interesting at z~1
- **Only x-ray astronomy can measure how, where and when most of the energy that controlled how universe formed was produced**

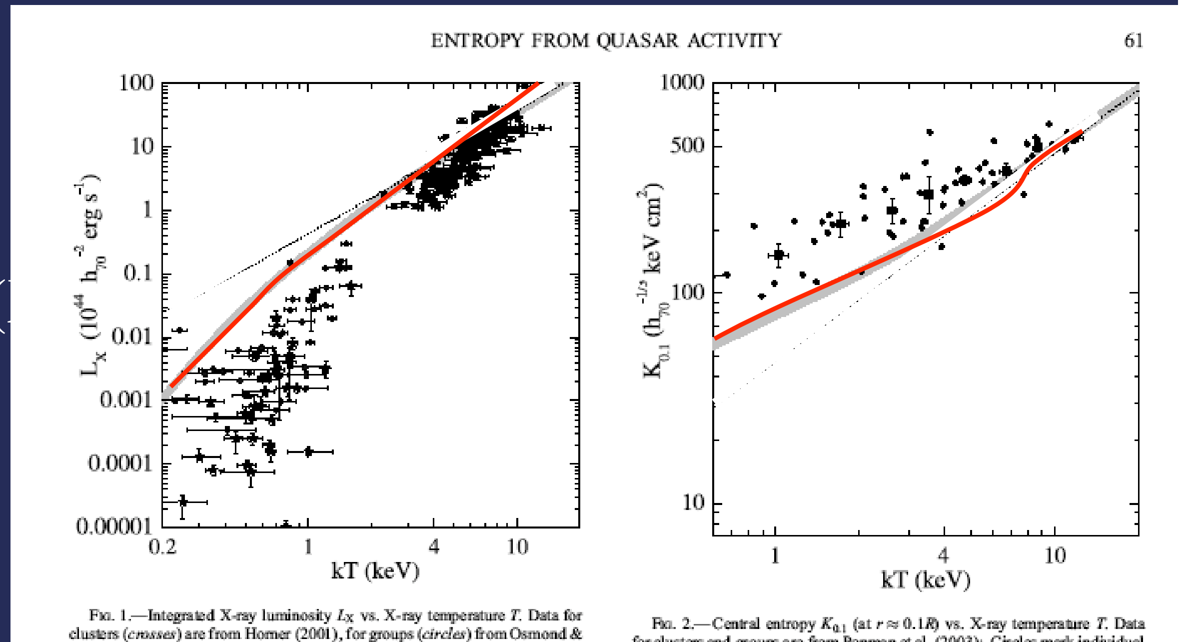


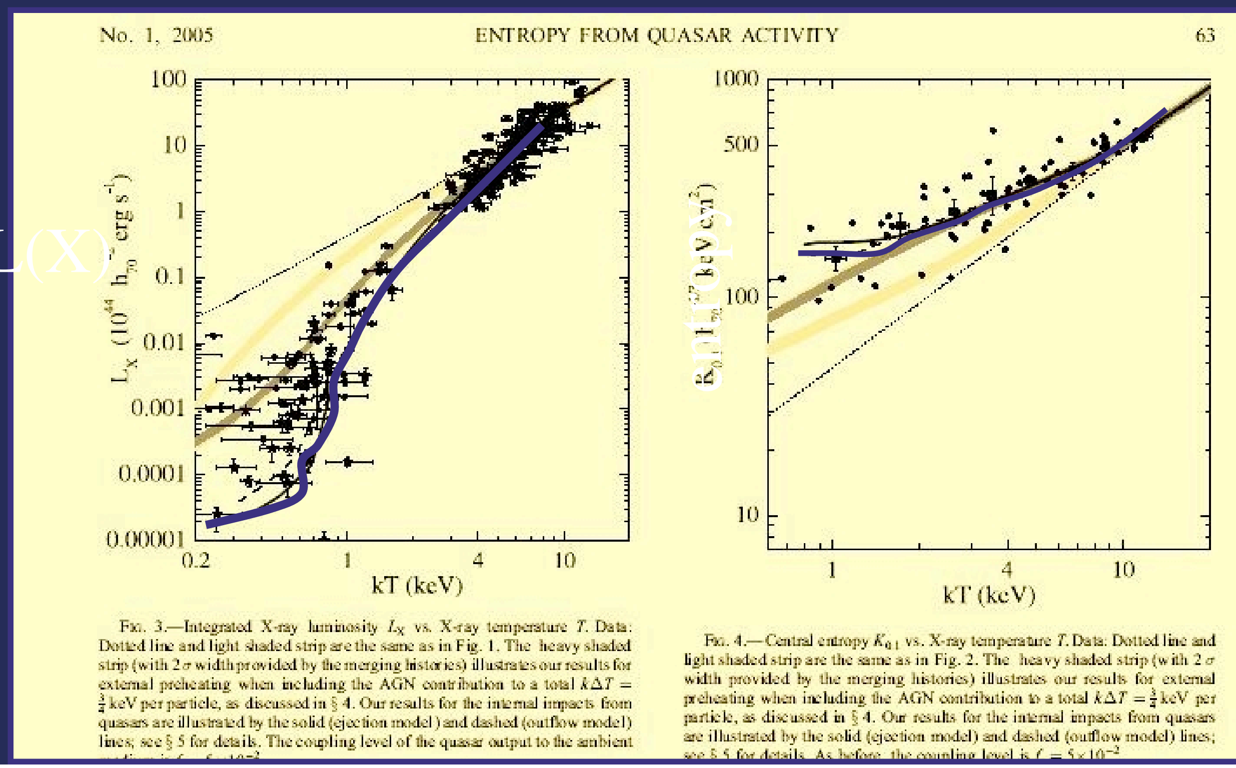


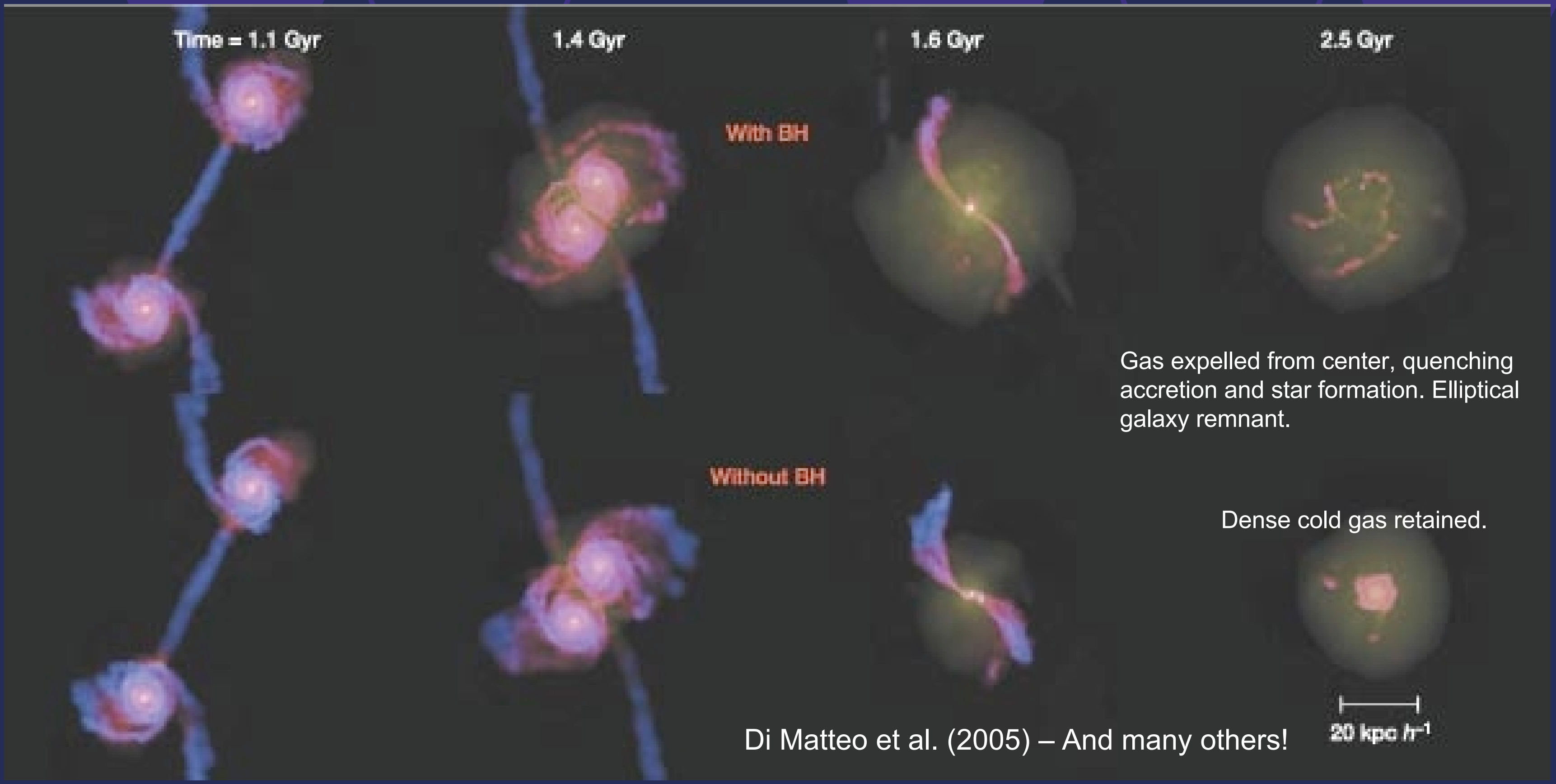


Ettori et al 2004

- - the effects of star formation and cooling are not sufficient to produce the observed entropy profiles
- AGN heating (both internal and pre-heating) of same order to solve the galaxy formation problem ‘works’ to solve entropy







Quasar feedback can strongly affect black hole fueling and star formation in host galaxy.

Feedback likely from a wind, but details of feedback remain uncertain. Better feedback modeling needed.

Perhaps can explain SMBH mass vs. bulge velocity dispersion.

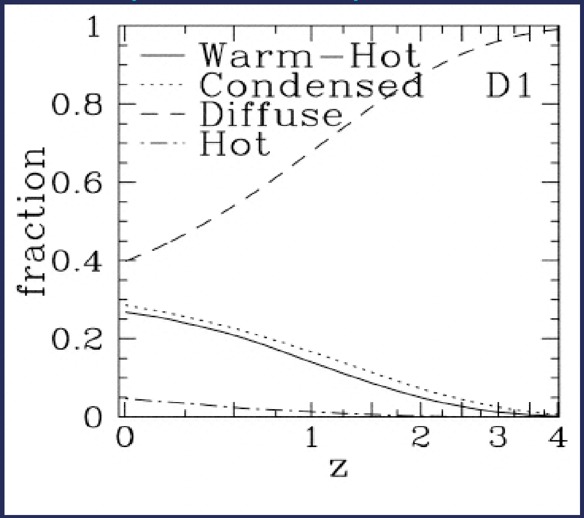
Could hope to see gas being expelled via observations of X-ray absorption.

The 'missing' baryons and the WHIM

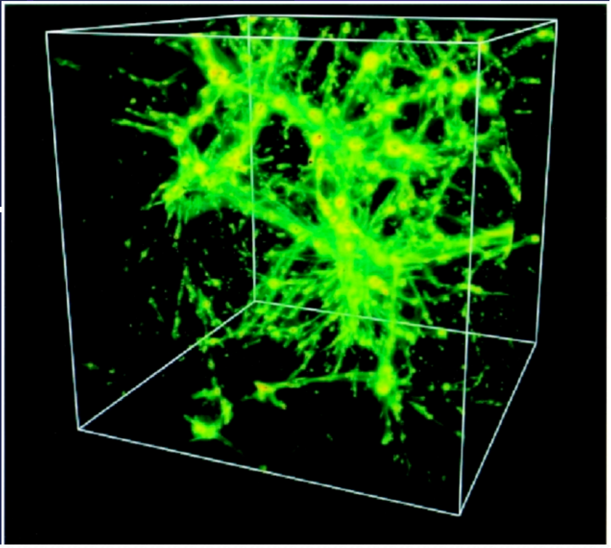
- BBN + CMB: Ω_b=(4.6±0.4)%.
  - z>2, Damped-Ly-α pop. + Ly-α clouds
  - z<2, Ly α abs. + galaxies + clusters = (2.5±0.3)%.

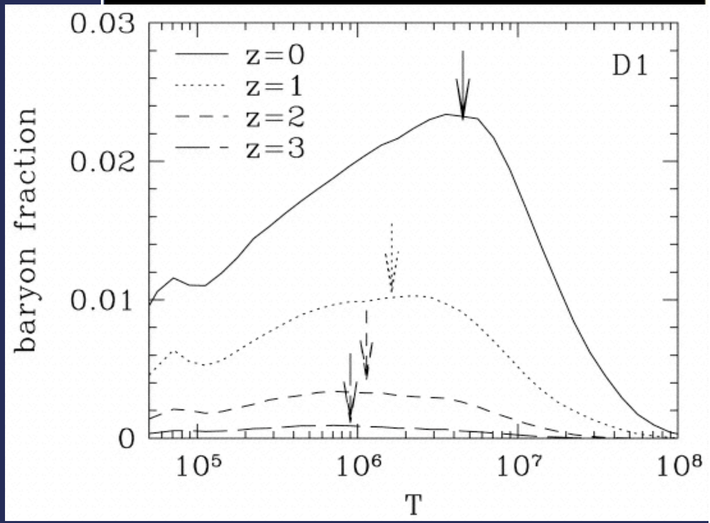
~ 50% of the baryons are 'missing'

- In WHIM (filaments) at low z ?



[Dave etal. 2001]





- IGM hotter towards low z due to shock heating
- Extra heating might be present due to SF & AGNs

Large fraction of baryons at T~10^5-10^7 K

Detect (started) and study properties (d$\mathcal{N}$/dzdN, temperature, metallicity) versus z

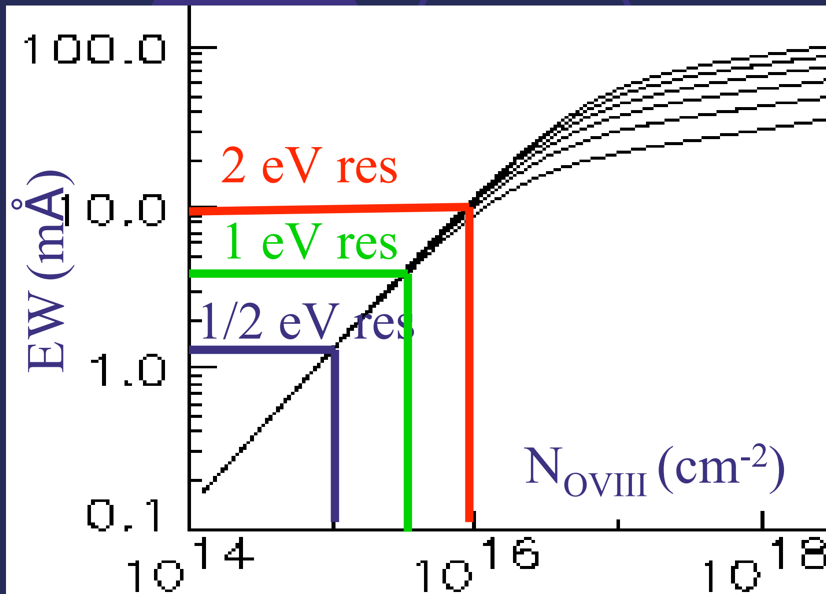
Probe LSS/galaxy formation

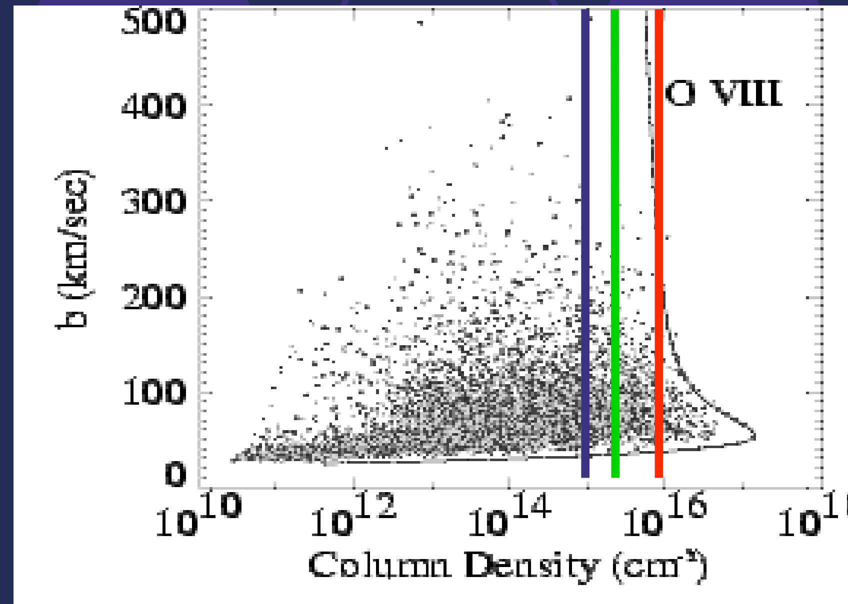
Mission requirements

  - Sufficient spectral resolution to measure winds in AGN and starburst galaxies and turbulence in groups >400km/sec- 2 eV at 600 eV
- Sufficient sensitivity to measure reasonable samples of these objects
- Sufficient angular resolution to locate turbulence/mass motion in 'nearby' groups clusters 5"
- Low enough background to measure winds and surface brightness of groups

THIS is the picture of the Animal that came out of the sea and ate up all the food that Suleiman-bin-Daoud had made ready for all the animals, in all the world.

Mission requirements





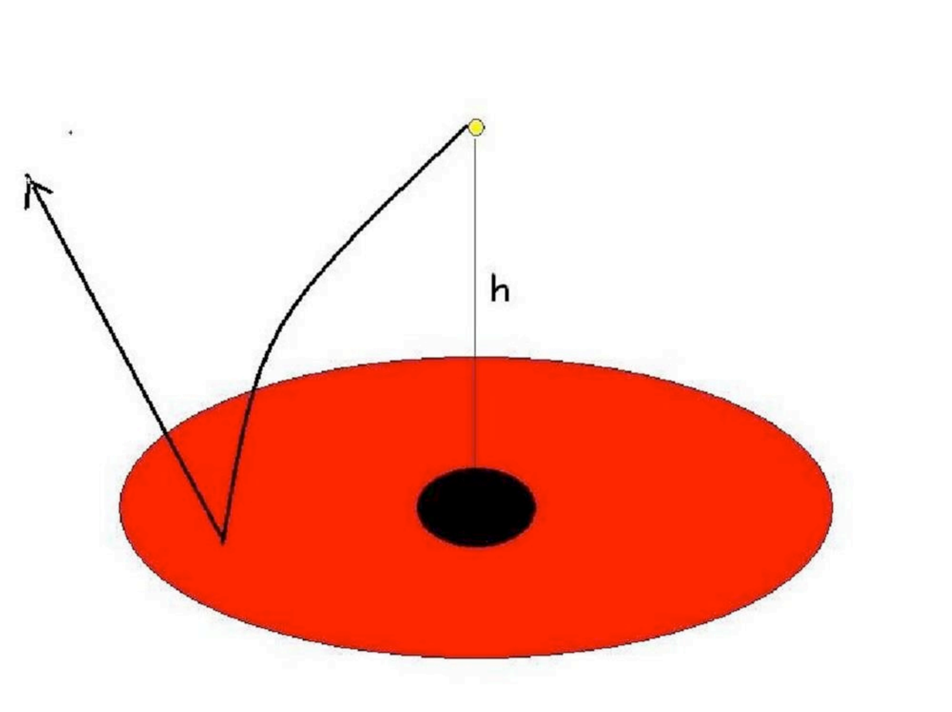
(S/N) ~ 50 x $[(S_{eff}/10\ m^2)QE\ t/(100\ ks)\ S/(10^{-13}\ erg\ cm^{-2}\ s^{-1})]^{1/2}\Delta^{-1}$ (eV)

Sensitivity (EW) ~ Δ/10

Cryo imaging spect		Gratings
Δ ~1 eV	Shorter exposures	Δ ~0.1 eV
	Higher z	
QE~0.5-1	Weaker absorbers	QE ~ 0.03
	Broader sampling	
	More detailed sampling	

The AGN unified scheme was conceived after the optical polarimetric observations of NGC 1068 (Antonucci Miller 1985)

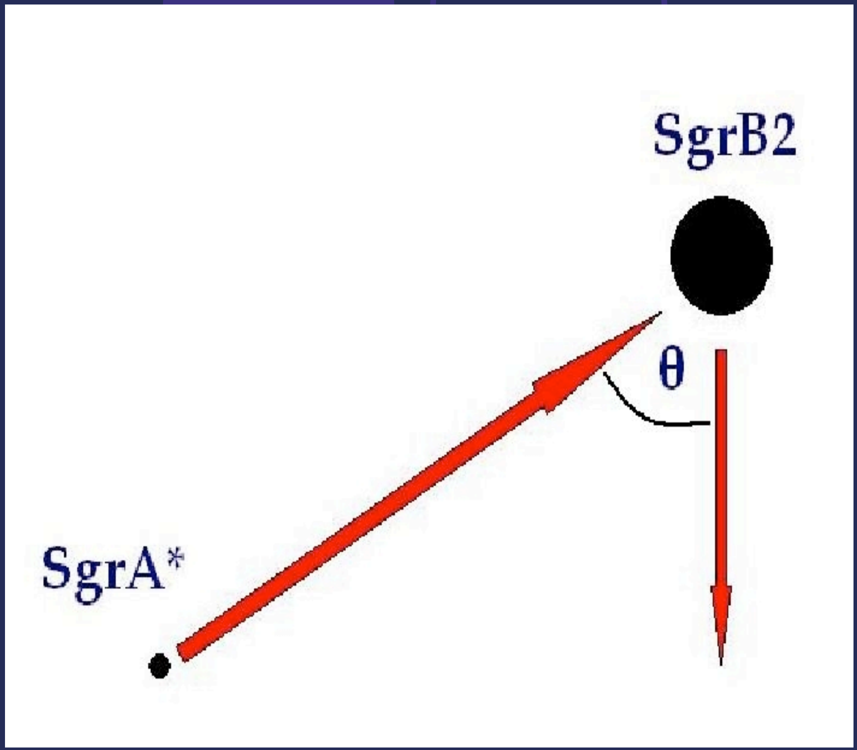
X-ray polarimetry is an unexplored and potentially rich field

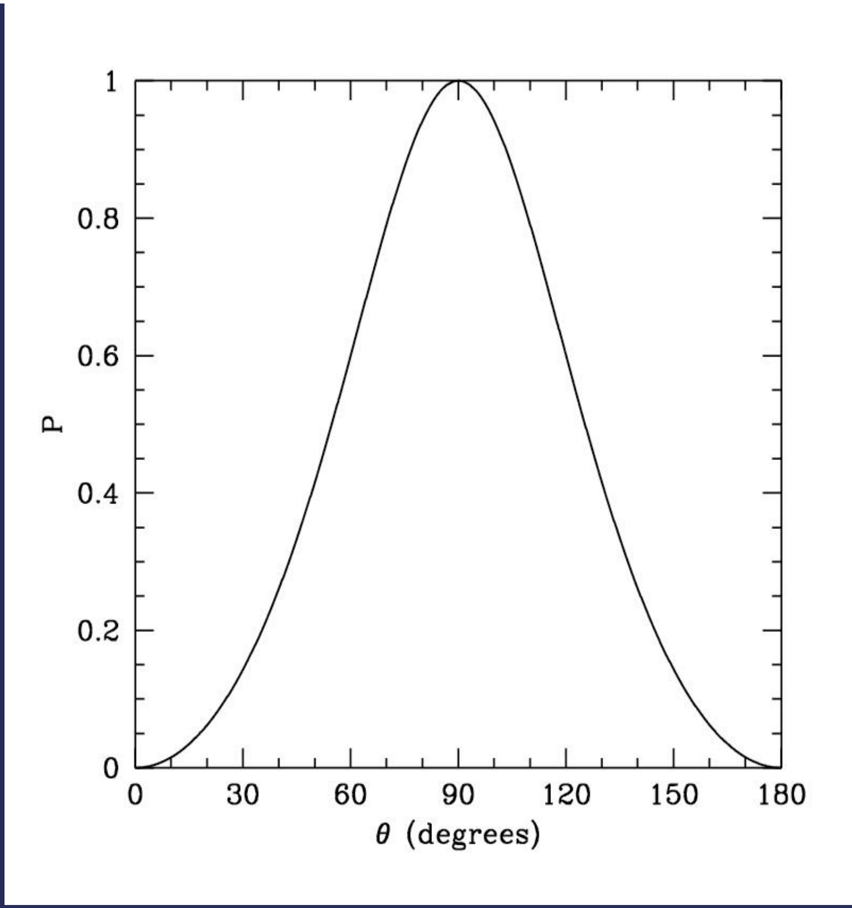


Bending model (Miniutti et al.)

The reflected disk emission is
Expected to be polarized

In GR the
polarization angle is a function
Of illuminating source heigth





Reflection nebula in the Galactic center ◊ echoing the past activity
Of our Galactic center ◊ polarization angle perpendicular to the
Projected line between the BH and the nebula

- ASTRO E-2
- NuStar / NEXT / Simbol-X
- Large investement of Chandra and XMM time in the next few years

- Help to better focus the scientific priorities